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## (54) COMBUSTION GAS GENERATOR


(71) We, THIOKOL CORPORATION, a corporation organised under the laws of the State of Virginia, United States of America, of P.O. Box 27, Bristol, Pennsylvania 19007, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—


This invention relates broadly to combustion gas generators; and particularly to solid fuel gas generators suitable for rapidly filling inflatable structures in the presence of humans.

Of particular interest in the present invention is its use for inflating safety cushions in passenger carrying vehicles. Such cushions are designed to be inflated rapidly and automatically to protect human occupants in the event of a collision of the vehicle with some other object.

Solid fuel gas generators for this purpose are known in the prior art. For example, U.S. Patent 2,779,281 to Maurice et al; U.S. Patent 3,305,319 to Kowalick et al; U.S. Patent 3,515,518 to Halstead et al; and U.S. Patent 3,558,285 to Ciccone et al all teach gas generators using a solid gas generating material. However, all of these inventions are characterised by linear, sequential arrangements of the igniter, solid fuel, filtering means, and cooling means in cylindrical housings. Such structures have certain disadvantages in that they tend to be bulky, slow in response time, and tend to deliver damaging jets of gas to the structure to be inflated.

It is an object of the present invention to provide an improved gas generator.

In its broadest aspect, the invention consists in a gas generator comprising: ignition means; a gas generating composition surrounding the ignition means, the ignition means being operable to cause the gas generating composition to produce gases; an outer housing surrounding the gas generating composition, and having peripheral orifices for the expulsion of gases when produced by the gas generating composition; and cooling means between the orifices and the gas generating composition to cool the gases when produced by the latter.

From another aspect, the invention consists in a gas generator comprising; an electric ignition device; a perforated enclosure surrounding the ignition device; pyrotechnic material in the enclosure; a hermetically sealed, cylindrical, aluminium container enclosing the perforated enclosure and defining an inner annular chamber around it, the container being rupturable by gas pressure when built-up in the inner annular chamber; a pelletized gas generating composition in the inner annular chamber; annular, spiral wrappings of fine wire mesh screen inside the container adjacent the cylindrical wall thereof; a cylinder having orifices near one end, surrounding the container; an outer housing enclosing the container and cylinder and forming an outer annular chamber around the cylinder, the outer housing comprising two shell halves, threadedly engaged, one of which is concave, the other having peripheral orifices therein, and a mounting flange fixed to one of the shell halves; and a cooling device in the outer annular chamber between the orifices of the cylinder and those of the housing comprising annular wrappings of wire mesh screen.

The invention also consist in an inflatable safety cushion for passenger-carrying vehicles incorporating a gas generator as above defined.

In one embodiment, the gas generator is of basically annular construction. A central ignition means is surrounded by a gas generating composition, and both are enclosed by a hermetically sealed, rupturable container having an annular filter between the gas generating composition and the walls of the container. An inner housing having peripheral, generally radial orifices surrounds the container, and an outer housing forming an annular chamber surrounding the inner housing also has peripheral, generally radial orifices. A cooling device is positioned in this annular chamber between the two sets of orifices, and an optional material for pH neutralization of gases is included between the orifices of the inner housing and the

cooling device. A mounting flange is fixed to the outer housing for mounting the gas generator to related apparatus.

When the ignition means ignites the gas generating material, the resulting gases rupture the container adjacent the orifices of the inner housing. Solid particles that may be contained in the gases are removed by the filter. The gases then pass through the pH neutralizing material and the cooling device before being expelled into an inflatable structure.

Two important properties that must be inherent in a gas generator for inflating safety cushions for automotive vehicles are: (1) it must inflate the cushion very rapidly (within 35 milliseconds): and (2) the gases produced must be cool enough so that there is no danger of burning the occupants of the automobile. These properties are ordinarily exclusive because gas generating compositions that burn rapidly usually burn with high temperatures. Prior-art gas generators have relied on rapidly burning gas generating compositions coupled with elaborate means for cooling the gases. Various chemical and mechanical cooling means of the prior art, however, have been found to be either unreliable after long periods of storage or unacceptably bulky. In gas generators embodying the present invention as hereinafter described and illustrated, both cooling and speed of reaction are promoted by the mechanical design of the gas generator. As a result, a cooler-burning gas generating composition may be used and still deliver gases to the inflatable structure within a required time. The speed of reaction is enhanced by the fact that the gas generating material surrounds the ignition means; so that a greater proportion of the gas generating material is directly exposed to hot gases and flame therefrom. Also, both cooling and speed are enhanced by the fact that the gases from the gas generator expand rapidly in all directions rather than linearly through a cylinder.

In addition to speeding the production and delivery of gases so that a cooler-burning gas generating composition may be used, other valuable and unexpected properties that result from the embodiment employing the annular design are; (1) the gases produced are automatically diffused and not concentrated into jets that may damage an inflatable structure; (2) the annular expulsion of gases from the gas generator ensures that the gas generator will not be propulsive and function as a rocket inside an automobile in the event of a collision; (3) the filter and cooling means can be made easily, inexpensively, and simply by annular wrapping of wire mesh screen—which may be easily adjusted in size by adding or subtracting wrappings (4) there is greater immediate exposure of all gases to the filtering and cooling means, since there is a very large, annular, filtering area; and (5) the very rapid, radial expansion of the gases from the gas generator creates a refrigeration effect that helps to cool the gases.

In order that the invention may be more readily understood, reference will now be made to the accompanying drawings, in which:—

The single Figure is an axial sectional view through a circular gas generator embodying the invention.

Referring to the drawing, the gas generator includes ignition means comprising a conventional electric squib 4 surrounded by pyrotechnic material 5 in a perforated enclosure having the form of a cylinder 6 with an end cap 7. The squib 4 is supported in a mounting adapter 8. Although any one of a number of pyrotechnic materials may be used, a preferred material is a granular mixture of 25% by weight of boron and 75% of potassium nitrate. The ignition means also includes rupturable diaphragm 9 surrounding the perforated cylinder 6. This disphragm 9 is in turn surrounded by the gas generating material 10, which is surrounded by an annular filter 11. The diaphragm 9 serves the dual purpose of retaining the granular pyrotechnic material 5 in the perforated cylinder 6 and of ensuring that the gases produced by the pyrotechnic material have sufficient pressure to permeate the gas generating material thoroughly for efficient ignition before they are released by rupture of the diaphragm 9. Although the gas generating material 10 may be any one of a number of compositions meeting the requirements for burning rate, non-toxicity, and flame temperature, a preferred material is pellets of a mixture by weight of 55% sodium azide ($NaN_3$) and 45% anhydrous chromic chloride ($CrCl_3$).

This entire assemblage is enclosed in a hermetically sealed, rupturable container 12. The container 12 is preferably made of aluminium and comprises a drawn, cup-shaped member 13 sealed to an end disk 14 with a double-crimp seal 15, typical of metal containers used for preserving food and drinks.

The filter 11 is preferably made in two parts, a plurality of layers of fine mesh screen 16 (about 30 to 60 mesh) surrounded by a plurality of layers of coarse mesh screen 17 (about 8 to 16 mesh). The fine screen 16 filters any solid particles out of the gases, and the coarse screen 17 creates a plenum chamber between the fine screen 16 and the wall of the container 12 for build-up of gas pressure to rupture the container 12 and to provide a free-flow path for gases therefrom.

The container 12 is enclosed in an inner housing 18 formed by a cylinder 19 having peripheral orifices 20 near one end, an end

cap 21 that fits over the other end, and a concave half shell 22 of an outer housing 23. The concave half shell 22 has an annular mounting flange 24 and internal screw threads 25 for engagement with a convex half shell 26. The convex half shell 26 has external threads 27 and peripheral orifices 28. An annular space 29 between the inner housing 18 and the outer housing 23 contains a cooling device 30, and, optionally, a substance 31 for neutralizing the acidity or alkalinity of the gases. The cooling device 30 is formed by annular, spiral wrappings of wire mesh screen and is retained in position between the orifices 20 of the inner housing 18 and those 28 of the outer housing 23 by a flange 32 on the end cap 21 and an annular retaining member 33. The flange 32 and the annular retaining member 33 have perforations 34 to permit the flow of gases through the screen comprising the cooling device 30. An annular supporting member 35 retains the pH adjusting material 31 in a position adjacent the orifices 20. A preferred material 31 is packaged in a toroidal tube of plastic film and comprises powdered iron sulphate, $Fe_2(SO_4)_3$ or $FeSO_4$.

The squib mounting adapter 8 is retained in the concave shell 22 by a snap ring 36 that fits into a groove 37 of the adapter and into a recess 38 of the half shell 22. The wall of the outer housing 23 is confined between the snap ring 36 and a shoulder 36*a* on the adapter 8, for retention of the adapter. It is also sealed relative to the half shell 22 by an elastomeric composition 39. An annular, elastomeric, O-ring seal 40 is confined at the juncture of the two half shells 22 and 26 by the retaining member 33 to prevent escape of gases therethrough.

Although the half shell 22 of the outer housing 23 is made concave so that is will fit over parts typically assembled on the steering column of an automobile, this design also provides the environment for another important feature; Because the half shell 22 is concave at its junction with the inner housing cylinder 19, a deep, annular trough 43 is formed. In order to prevent possible failure of the wall of the container 12 over this trough 43, the container wall is drawn by a stamping die into a form that fits into the trough 43 so that it may be directly supported by the sides thereof. While this additional drawing solves the problem of supporting the wall of the container 12 over the trough 43, it may also produce the surprising and valuable result of thinning the wall of the container 12 in the vicinity of the orifices 20 sufficiently to ensure prompt rupture of the container 12 through the orifices 20 when the gas generating material 10 is ignited. This is a very valuable result, because it may otherwise be necessary to subject the container 12 to expensive, precision machining to ensure its prompt rupturability adjacent the orifices 20.

The container 12 is mass produced by conventional machinery used for forming and sealing beverage cans; and, to be reliably handled and formed by such machinery, the starting aluminium sheet stock is about 16.5 mils thick. This thickness, however is too great to be reliably ruptured with maximum speed by gases produced by the gas generating material 10. Hence, it is a very useful result that the wall of the container 12 may be made approximately 5 mils thick in the vicinity of the inner housing orifices 20 by the process of drawing it into a shape that will fit into the trough 43. The 5 mil thickness is optimum both for reliably maintaining strength and the hermetic seal of the container 12, and, at the same time, for reliably rupturing when subjected to the gas pressure produced by the gas generating material 10.

The gas generator herein described and illustrated is suitable for inflating structures in the presence of humans since it has a very rapid response and can deliver gases which are sufficiently cool so that there is no danger of burning human occupants of a vehicle. The generator is nonpropulsive; the gases are automatically diffused and cannot damage the inflatable structure; the solid fuel is hermetically sealed and, hence, reliable after years of storage; and filtering and cooling means may be achieved easily and inexpensively by annular wrappings of screen mesh material in the generator. Also, the annular design is very adaptable to the steering column of an automobile, and the structure is simple and easy to manufacture.

WHAT WE CLAIM IS:—

1. A gas generator comprising:
   ignition means;
   a gas generating composition surrounding the ignition means, the ignition means being operable to cause the gas generating composition to produce gases;
   an outer housing surrounding the gas generating composition, and having peripheral orifices for the expulsion from the outer housing of gases when produced by the gas generating composition; and
   cooling means between the orifices and the gas generating composition to cool the gases when produced by the latter.

2. A gas generator as claimed in claim 1, wherein the gas generating composition annularly surrounds the ignition means in contact therewith, the generator further comprising:
   a hermetically sealed container surrounding the ignition means and gas generating composition, which container is rupturable by gas pressure built up in the container after ignition of the gas generating composition; and

an inner housing surrounding the container and having peripheral, generally radial orifices for the expulsion of gases from the container and inner housing after rupture of the container;

the outer housing having generally radial peripheral orifices, and surrounding the inner housing, defining an annular chamber therewith, and the cooling means being located in the annular chamber between the orifices in the inner and outer housings, so that gases to be expelled from the outer housing will pass therethrough.

3. A gas generator as claimed in claim 2, wherein the cooling means comprises annular layers of wire mesh screen wrapped around the inner housing.

4. A gas generator as claimed in claim 2 or 3, further including an annular filter inside the container, adjacent the orifices in the inner housing.

5. A gas generator as claimed in claim 4, wherein the container has an annular wall, and the annular filter comprises;

a plurality of annular layers of relatively coarse wire mesh screen covering the inside surface of the annular wall of the container; and

a plurality of annular layers of relatively fine wire mesh screen substantially covering the coarse wire screen, the fine screen being operable to remove any solid particles, from the gases produced, and the coarse screen providing a plenum chamber to promote free flow of gases through the orifices in the inner housing.

6. A gas generator as claimed in claim 5, wherein the coarse screen is of the order of 8 to 16 mesh, and the fine screen is of the order of 30 to 60 mesh.

7. A gas generator as claimed in any of claims 2 to 6, wherein the container is made of sheet aluminium and comprises a cup-shaped member and a disk member, double-crimp, hermetically sealed together.

8. A gas generator as claimed in any of claims 2 to 7, further including a mounting flange fixed to the outer housing.

9. A gas generator as claimed in any of claims 2 to 8, wherein the outer housing has an end wall which is outwardly concave.

10. A gas generator as claimed in any of claims 2 to 9, wherein the inner housing comprises a hollow cylinder and portions of the outer housing, fitted together to form an enclosure.

11. A gas generator as claimed in claim 9 in combination with claim 10, wherein the cylinder has orifices near one end thereof, wherein said one end contacts the inner convex side of the outwardly concave end wall of the outer housing, and wherein, at the juncture of the cylinder with the end wall there is formed a relatively deep annular trough inwardly of the cylinder, the wall of the container being shaped to at least partially fit the trough and be supported by the sides of the trough and, in the region of the orifices in the cylinder, being made sufficiently thin to be readily rupturable by gas pressure when built up in the container.

12. A gas generator as claimed in claim 11, wherein the container is formed from a relatively ductile sheet metal, the wall of the container being drawn to shape it to at least partially fit the trough and to reduce its thickness in the region of the orifices.

13. A gas generator as claimed in claim 12, wherein the sheet metal is aluminium.

14. A gas generator as claimed in any of claims 2 to 13, further including a material for neutralizing the pH of the gases produced, the material being positioned in the annular chamber between the cooling device and the orifices in the inner housing.

15. A gas generator as claimed in claim 14, wherein said material is powdered iron sulphate.

16. A gas generator as claimed in any preceding claim, wherein the ignition means comprises:

an electric squib;

a pyrotechnic composition surrounding the electric squib;

a perforated enclosure around the squib and pyrotechnic composition; and

a rupturable diaphragm around the enclosure, to retain the pyrotechnic material in the perforated enclosure and to enable build up of gas pressure therein after ignition of the pyrotechnic material before rupture of the diaphragm.

17. A gas generator as claimed in claim 16, further including:

a mounting adapter into which the squib is fitted, and which extends partially through a hole in the outer housing and has a shoulder on the inside of the housing;

a snap ring fitted into a groove in the portion of the adapter outside the housing, so that the housing wall is confined between the shoulder and the snap ring; and

an elastomeric seal between the adapter and the housing.

18. A gas generator as claimed in claim 16 or 17, wherein the pyrotechnic material is a mixture of about 25% by weight of boron and about 75% of potassium nitrate.

19. A gas generator as claimed in any preceding claim, wherein the gas generating composition comprises a pelletized composition.

20. A gas generator as claimed in claim 19, wherein the gas generating composition comprises pellets of a mixture of about 55% by weight of sodium azide and about 45% of anhydrous chromic chloride.

21. A gas generator comprising:

an electric ignition device;

a perforated enclosure surrounding the ignition device;

pyrotechnic material in the enclosure;

a hermetically sealed, cylindrical, aluminium container enclosing the perforated enclosure and defining an inner annular chamber around it, the container being rupturable by gas pressure when built up in the inner annular chamber;

a pelletized gas generating composition in the inner annular chamber;

annular, spiral wrappings of fine wire mesh screen inside the container adjacent the cylindrical wall thereof;

a cylinder having orifices near one end, surrounding the container;

an outer housing enclosing the container and cylinder and forming an outer annular chamber around the cylinder, the outer housing comprising two shell halves, threadedly engaged, one of which is concave, the other having peripheral orifices therein, and a mounting flange fixed to one of the shell halves;

a cooling device in the outer annular chamber between the orifices of the cylinder and those of the outer housing comprising annular wrappings of wire mesh screen.

22. A gas generator constructed substantially as hereinbefore described with reference to the accompanying drawings.

23. An inflatable safety cushion for passenger-carrying vehicles incorporating a gas generator as claimed in any preceding claim.

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